ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE) Vol. 3, Issue 7, July 2017

Iris Verification Based on Spatial Distribution of the Local Average Gradient Density

Dr. Iman Abduljabbar Saad[1], Dr. Loay E. George[2]
Lecturer, Electronic Computer Center, Al-Mustansiriyah University, Baghdad, Iraq[1]
Associate. Prof. ,Department of Computer Science, College of Science, Baghdad University, Baghdad, Iraq[2]

***Abstract*—The iris structure offers many properties like stability,uniqueness, easy measurement and high recognition rate, which makethe iris authentication so accurate. In this paper, an irisverification system is proposed using local textural features to achieve high authentication accuracy, so, two different sets of textural features have been suggested to represent the iris texture attributes; they depend on the spatial variation of the intensity of localized iris area. The introduced features sets are: (i) Spatial Distribution of the Local Average for First Gradient Density (SDLAFGD), and (ii) Spatial Distribution of the Local Average for Second Gradient Density (SDLASGD).As well, this work focuses on the selection of proper features to authenticatethe individuals. Normalized Mean Square Difference (NMSD)measure was used to make the similarity matching decision. The system was tested using public database CASIA V1.0, the best achieved results indicated verification rate (99.74%).**

Keywords: Biometric, Segmentation, Gradient, Feature extraction, Iris verification.

I.INTRODUCTION

Individuals typically utilize user name, password, identification card, Personal Identification Number (PIN) and key to verify that they are who they assert to be. However, security can smoothly be breached in these systems when the access card or the key is stolen or missing. It was found that the enormous importance in amended methods of authentic and safe authentication of the person averts the problems combined with formal methods. Among usable authorized methods, biometrics method can automatically recognize a person based on his or her behavioral or physiological features by computers. Such technology has taken a big amount of care and concern for security in nearly all aspects of our daily lives since individual cannot lose or forget their physiological features in the way that they might lose an identity card or password, various physiological, traits in the person show a considerable inter individual variability: fingerprints,, palm prints, ear's shape, the iris pattern, among others [1], [2]. Therefore, the model of personal authentication has turn from the use of "something that individual remember" (e.g., password) or “something that an individual has” (e.g., key or identification card) to “something that an individual is” which embraces biometrics that base on the measuring certain physical's characteristic or personal's trait (e.g., finger-print, face image, iris, ear print, signature, gait or voice and other identifier). Between all the biometric, systems, iris recognition has become an active research topic in the area of pattern recognition because of its increasing demands in identity authentication[3].

II. PREVIOUS WORKS

The following are some of the published researches in the iris verification methods which lead to different performance results:

In 2012, R. Hentati and *et al*[4] have proposed paper focused on the iris modality. The process of iris recognition containing three phases: preprocessing and segmentation, encoding and comparison. In the first phase they used filter smoothing and Hough transform. The Gabor filter using in the second phase and Hamming distance applying in the third phase. The test was on the CASIA v1.0 database. The iris verification processing is executed and gives an overall accuracy of 92.04% with FAR of 1.58% and FRR of 2.34%.

In 2013, V. R. E. Chirchi and L. M. Waghmare [5], proposed system focuses on feature extraction using five level decomposition techniques implemented with Haar, db2 and db4 and achieve high accuracy with reduced error rates. The training image considers were 756 iris images of the CASIA v1.0 database and testing images were 100. They are system results were quite encouraging with false Non match rate of 0.025% and false match rate of 0.033% for Haar wavelet with different hamming distance and final verification accuracy was 99.972.

In 2014, Ali [6] proposed iris recognition method using different combinations of Haar wavelet, GLCM and Run Length Matrix (RLM) features for feature analysis and evaluation. The attained verification rate was 98.8% for CASIA,-v1.0.

In 2015, Abdullah [7] proposed approach to get more accuracy of the iris authentication which is used wavelet transform for two types of filter, Haar and Daubechies

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(IJARMATE) Vol. 3, Issue 7, July 2017

(db4) in order to extract the features and finally using the matching by artificial feed forward neural network with back propagation algorithm for training and testing iris image. In the experiment; for both filters (Haar& db4) he used 10 persons authorized, 5 persons unauthorized and each person has 3 images belong to CASIA v1.0 database. The use of filter Daubechies gives better results than the filter Harr; the performance is equal zero of FAR and 25% of FRR.

In this work, a reliable and accurate iris authentication (verification) systemis proposed, based on using local textural features to achieve high accuracy. To ensure efficient system performance many robust and fast methods are introduced to accomplish the iris segmentation and authentication tasks from eye images captured in less controlled circumstances and non-excellent environment. Since the iris texture contents show a sort of location dependency, a set of spatial textural features are introduced as significant discriminating feature. Also, this work focuses on defining smallest sets of optimal features which can lead to high verification throughputs.

III.PROPOSED LAYOUT

Fig.1 shows the major phases of the proposed authentication (verification) system. The main two phases that the proposed system consists are:

Phase1- Enrolment:In this phase, after the operations of pre-processing (i.e. iris segmentation, iris normalization, eyelashes and eyelids detection), iris enhancement, gradient determination, partitioning and feature extraction are applied on the iris for each person. The extracted features are manipulated through the features analysis step to decide which of these features are stable to build the templates of feature vector to store it in the database.

Phase2- Authentication (verification):In this phase, after the operations of pre-processing, iris enhancement, gradient determination, partitioning and feature extraction are applied on the iris for the tested person iris, the extracted features vector will be matched with templates that stored in the database, to make a decision. The matching will be (1:1); the system should match the gain feature vector with the corresponding template and return a decision that verifies the claim of that person.

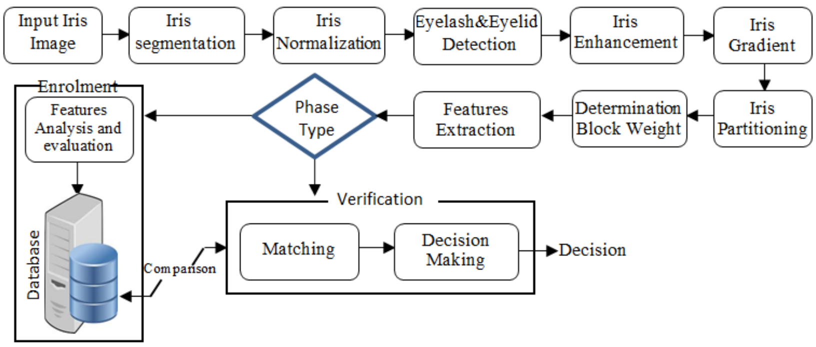

Fig.1.The proposed system layout.

A. Pre-Processing

The most important step in iris authentication systems is the iris segmentation, because all the sub-sequent stages depend on its accuracy. Segmentation should be applied for localizing and extracting iris area from the image. In our method described in [8], a fast and accurate algorithm for detecting the boundaries between pupil and iris and between sclera and iris had been proposed, which is mainly composed of three main stages. The first stage is for image enhancement using normalization process. The second stage is for localization of inner boundary; it is consist of many sub stages: (i) thresholding, (ii) image denoising, (iii) circular pupil boundary localization and(iv) circle fitting. The last stage is for localization of outer boundary. Fig. 2 shows samples of detected iris regions using our developed method. The attained localization accuracy rate for this approach was 100%.

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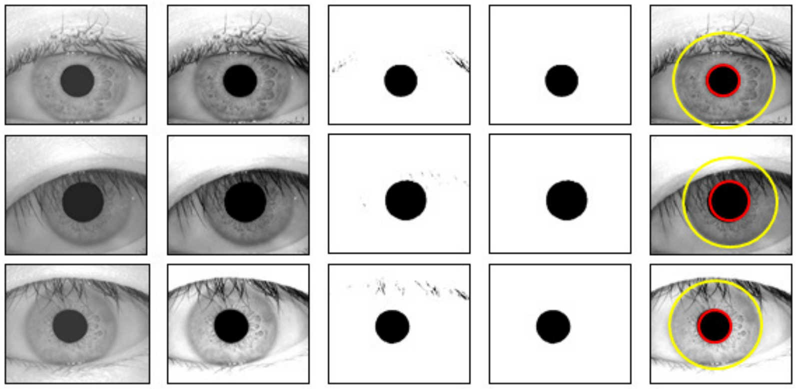

(a) (b) (c) (d) (e)

Fig.2. Iris Segmentation.(a) original images from CASIA V1.0, (b), Enhanced iris images, (c) binary images, (d)Detect max pupil's segment and circle fitting, (e) inner and outer iris boundary detection.

After that, the iris(ROI) is normalized (i.e., mapped)to a rectangular flat region. The eyelids and eyelashes are detected as a noise points, these noisy points are avoidedwhen creating template features.

B.Iris Enhancement

Normalized iris image should be enhanced before features extraction, because these images has low contrast and may have non uniform brightness caused by different position of light sources, and this problem will be effect the following feature extraction and matching process. Therefore contrast stretching is adopted to enhance normalized iris image to get an image with uniformly distributed brightness and have better contrast; the purpose of contrast stretching is to bring the iris image into intensity range that is more normal or suitable for features extraction phase.

At first, we compute the mean (M) and standard deviation (σ) of the normalized image using the following equations:

$$M=\frac{1}{Lxw}\sum_{i=0}^{255}\text{Hist}(i)*i \qquad (1)$$

Where Lxw is the resolution of the image, Hist(i) is the total number of pixels in the i^{th} gray level.

$$\sigma=\frac{1}{Lxw}\sum_{i=0}^{255}\text{Hist}(i)*(i-M)^2 \qquad (2)$$

The applied mapping function for contrast stretching can be found by the following equation:

$$G'(x,y)=\frac{A}{\sigma}*(G(x,y)-M)+128 \qquad (3)$$

Where, G (x,y) is the pixel's intensity and G′(x,y)is the mapped pixel value.The suitable value of (A) parameter which controls the strength of stretching, was set to 100 in the conducted tests, the results of enhancement is shown in Fig. 3.

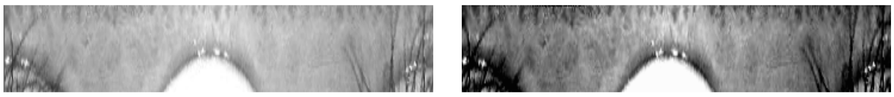

Fig. 3.Enhanced image. (a) Original normalized image, (b) Enhanced normalized image.

C. Iris Gradient

Iris Gradient Using First and Second Order Operators. Apply local gradient operators on the iris pixels, the local gradient operators are applied on the iris pixels to gain the desired domain for extracting a set of features. Gradient operator measures the directional change of around a pixel; this first and second order degree of intensity change measure, captures the local textural behavior of the iris signal. Each element of the gradient output arrays represents the change in the intensity, along specific direction, at certain position in the original image. The gradient arrays (images) along the horizontal, vertical and diagonal directions of the first(G_X, G_Y, G_D) and second (G_{XX},G_{YY},G_{XX},G_{DD},G_{XY}, G_{YX},G_{D2}) gradient operators are computed according to the following equations:

$$G_X(x, y) = P(x, y) - P(x+1, y) \qquad (4)$$

$$G_Y(x, y) = P(x, y) - P(x, y+1) \qquad (5)$$

$$G_D(x, y) = P(x, y) - P(x+1, y+1) \qquad (6)$$

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$G_{XX}(x, y) = 2P(x, y) - P(x-1, y) - P(x+1, y)$ (7)

$G_{YY}(x, y) = 2P(x, y) - P(x, y-1) - P(x, y+1)$ (8)

$G_{DD}(x, y) = 2P(x, y) - P(x-1, y-1) - P(x+1, y+1)$ (9)

$G_{XY}(x, y) = P(x, y) - P(x+1, y) - P(x, y+1) + P(x+1, y+1)$ (10)

$G_{YX}(x, y) = P(x, y) + P(x+1, y) - P(x, y+1) - P(x+1, y+1)$ (11)

$G_{D2}(x, y) = P(x, y) - P(x+1, y) + P(x, y+1) - P(x+1, y+1)$ (12)

Fig. 4 shows examples of the first and second gradient images. Where, G_X is the horizontal gradient image, G_Y is the vertical gradient image , G_D is the diagonal gradient image, G_{XX} , G_{YY} and G_{DD} actually represent the gradient of gradient along horizontal, vertical and diagonal directions, respectively. The G_{XY} is the gradient of gradient along horizontal direction; G_{YX} is the mean of vertical gradient, G_{D2} is the gradient D_1 of the gradientD_2.

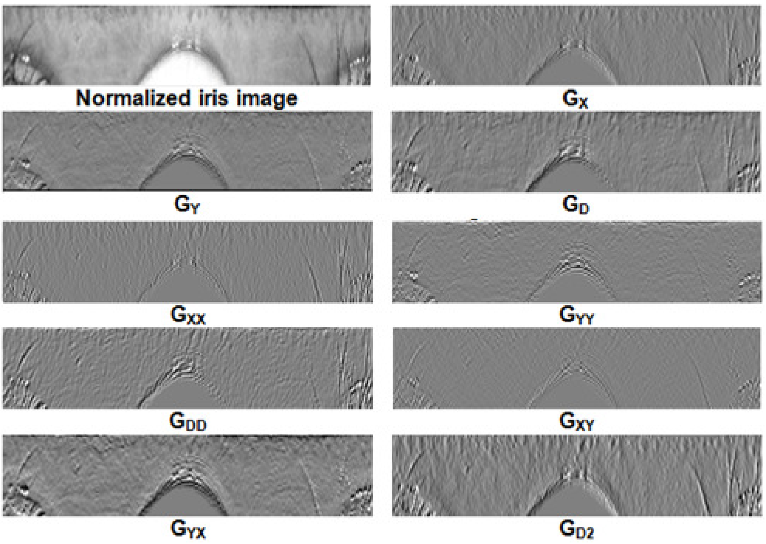

Fig.4.Examples of the first and second gradient images.

D. Iris Partitioning

Partitioning the gradient image into overlapped blocks with certain overlapping ratio (O_{Ratio}) along the horizontal (x) and vertical (y) directions, as shown in Fig. 5, the number of blocks along the vertical (n_y) and horizontal (n_x) directions should predefined, then the block dimensions (h_{block}, w_{block}) in both directions are determined.In our test the best number of blocks was 32 blocks (i.e., n_y=4 and n_x=8).

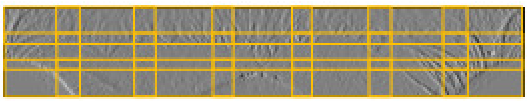

Fig.5. Examples of partitioning the iris image into overlap blocks horizontal and verticals.

E. Determine Block Weight

The non-linear weighting function (w_{Block}) as shown in the following equation is used to determine the significance of each block of the normalized iris image blocks (i.e. degree of discriminating trust).

$$W_{Block} = (1 - N_{Ratio})^{Gm} \quad (13)$$

$$N_{Ratio} = \frac{Number\ of\ noisy\ pixels\ in\ the\ block}{Block\ size} \quad (14)$$

The suitable value of Gamma (*Gm*) which can be within the range [1,9]. In this paper tests, the *Gm* value is set 7 for all different training samples because it gives trade-off results, and also this value of *Gm* allow the blocks which own a small percentage of noise points can have a good weight.

F. Features Extraction

Every iris image has distinctive feature that makes it distinguishable from other. So, good iris features should have high discrimination power in terms of identifying the iris images. In this step, the Spatial Distribution of the Local Average for First (M_{GX}, M_{GY}, M_{GD},) and Second (M_{GXX}, M_{GYY}, M_{GDD}, M_{GXY} , M_{GYX} and M_{GD2}) Gradient Density are determined

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International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE) Vol. 3, Issue 7, July 2017

(SDLAFGD and SDLASGD). The density (norms) is calculated for each iris block separately, and then they assembled in one features vector to be treated as a signature vector for the iris image.

The values of average density are calculated as iris features using the following equations:

$$M_{GC}(m) = \frac{1}{N_{iris}} \sum_{p(x,y)\in \text{block}} \left|G_C(x,y)\right|^m \quad (15)$$

$$M^S_{GC}(m) = \frac{1}{N_{iris}} \sum_{p(x,y)\in \text{block}} sign(G_C(x,y))\,|\,G_C(x,y)\,|^m \quad (16)$$

Where G_C is either G_X, G_Y ,G_D, G_{XX}, G_{YY}, G_{DD}, G_{XY},G_{YX} or G_{D2}; N_{iris} is the number of iris points (p) which belong to the block ($N_{iris}=H_{Block}xW_{Block}-N_{NoisePoints}$); m is the order of the norm for the components (G_C), and m=[0.5, 0.75, 1,1.5,2,3].

G. Matching

The tested iris is identified as belong to subject j if the distance measure with template j shows the lowest one. In the beginning, the *Wgt* value is calculated using the following equation:

$$Wgt=S(i).\ Weight(Ix, Iy)\ x\ T(j).Weight(Ix, Iy) \quad (17)$$

Where *S(i). Weight (Ix, Iy)* represent the weight of block number *(Ix, Iy)* which belongs to the tested i^{th} sample; and *T(j).Weight(Ix,Iy)* represents the template weight of block number *(Ix,Iy)* that belong to the j^{th} class.

In this system the weighted distance measures; Normalized Mean Square Difference (NMSD)has been used.

$$\text{NMSD}=WD(S_i,T_j)=\sum_{k=1}^{Nk}\left[\frac{S(i).f(Ix,Iy,k)-T(j).Mean(Ix,Iy,k)}{T(j).Std(Ix,Iy,k)}\right]^2 X\,Wgt \quad (18)$$

Where, *S(i).f(k)*denotes the value of k^{th} feature extracted from tested i^{th} sample; and *T(j).Mean(k)*, *T(j).Std(k)*are the template value of k^{th} feature belonging to j^{th} class and the corresponding standard deviation; for each block number *(Ix,Iy)*.

IV.VERIFICATION

The performance of proposed verification phase is evaluated using the Receiver Operating Characteristic (ROC) curve; it illustrates FRR against the FAR at different similarity distance threshold values. The performance is evaluated by computing EER measure; which is defined as the error rate of FAR and FRR when they are equal. EER indicates the minimum attained verification error, so, the threshold value is selected according to that minimum error. Small EER value indicates better verification performance. In order to measure FRR for the proposed method, the samples of each class have been matched against their template, while for measuring FAR, each sample of certain class is matched against all templates of other classes. The following section describe these measures for CASIAv1.0 databases which consist of 756 images belong to 108 class each class consist of 7 samples.

V.EXPERIMENTAL RESULTS

The verification performance of the proposed method is tested when using 4 best samples for training with combining of triple features of low order norm [G_D^0.5, G_{YX}^0.75, G_X^0.5] and left 3 samples for testing.The results of FAR, FRR and accuracy versus different threshold values are presented in Table (1) for all CASIA v1.0 database samples using the features belong to SDLAFGD and SDLASGD.

TABLE I: CALCULATION THRESHOLD VALUES FOR CASIA V1.0 DATABASE.

Threshold	FRR%	FAR%	Accuracy%
12.15	0.39683	0.23241	99.6853
12.25	0.26455	0.24353	99.7459
12.35	0.26455	0.26084	99.7373
12.45	0.26455	0.27568	99.7298
12.55	0.26455	0.29051	99.7224
12.65	0.26455	0.30411	99.7156
12.75	0.26455	0.32265	99.7064
12.85	0.26455	0.33996	99.6977
12.95	0.26455	0.35479	99.6903
13.05	0.13228	0.36592	99.7509
13.15	0.13228	0.38570	99.74101
13.25	0.13228	0.39683	99.7354

ISSN (ONLINE): 2454-9762
ISSN (PRINT): 2454-9762
Available online at www.ijarmate.com

International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE) Vol. 3, Issue 7, July 2017

The ROC curve between FAR and FRR for various threshold values is shown in Fig. 6, in the determined ROC curve, the EER point is equal to 0.26% and occurs at the threshold value of (12.35).

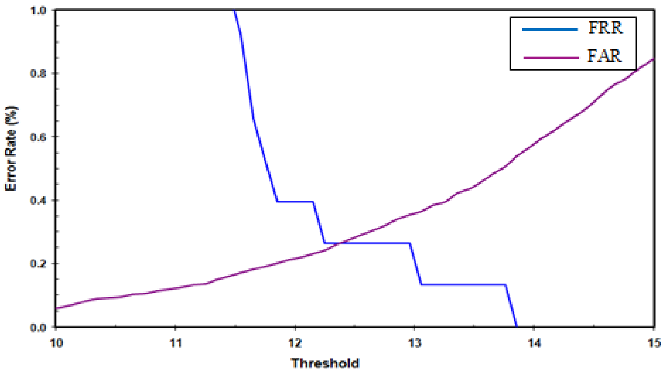

Fig.6.The ROC curve for verification results of CASIA v1.0 database.

The required time to perform pre-processing, feature extraction, and matching tasks was (0.737, 0.224and 0.00000722)respectively in seconds.All of thetestsand processes have been implemented using a lap-top computer (processor: Intel Core i7 CPU 2.40 GHz with 3.00 GB RAM), the operating system is Windows 7. The programming language Visual Basic is used to build and develop the required software.

VI.CONCLUSIONS

In this paper, a novel method is proposed for iris verification and extracts the distinctive iris featuresbased on the gradient components which are less susceptible to lighting, contrast and camera changes. Assigning a significant weight for each block through using weighting function to determine the effectiveness share of each block of the partitioned gradient image when making verification decision, helped to exclude the regions which have noisy points (i.e. eyelashes and eyelids) and avoid taking them into account when determining the template features. The benefits of using "feature sets derived from the spatial distribution of local average of pixels gradients" are: (i) it is applicable in spatial domain and reflects the directionality of iris textures, (ii) it is better detecting intensity changes corresponding to the smallest details and (iii) it is an indirect measure to the distribution of iris density at each part of image.The experimental results indicated that the combined features up to 3 had led to an optimal verification performance andmake the time needed for processing and matching as small as possible. Suggestions for future work are: (1)using clustering algorithm to partition the feature space into sub clusters (or sub-spaces) to create grand classes, such that each one contains many iris classes; this can speed-up the matching stage through using hierarchal matching scheme when the number of classes is very big, (2)developing the introduced IRS to use a part of the circular iris area instead of normalizing the whole area of it.

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